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ABSTRACT

This paper reports some results from a study sponsored by the Office of Naval Research that has focused on identifying sources of reading disability in young adults. Separate sections of the paper describe experiments conducted to investigate three sets of component processes--word analysis processes, integrative processes, and discourse analysis processes--and report some of the results of the experiments. The paper concludes that the studies have provided evidence for deficiencies in poorly skilled high school age readers in a host of component processes, that the sources of reading disability are not the same in all individuals, and that readers' deficits in component skills are reflected in the degree of efficiency or automacity they demonstrate, and not in their ability to correctly carry processing functions to completion. The paper includes a table and a list of results, charts, and sample exercises used in the experiments, all of which were originally presented with the paper in the form of slides. (GT)

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Component Skills in Readers of Varying Ability

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Bolt Beranek and Newman Inc.

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Today I would like to report on a three year ONR-sponsored study devoted to the problem of identifying sources of reading disability in young adults. The view I shall espouse is a pluralistic one: Skilled reading is, I believe, a result of the successful acquisition of a number of highly automatic, component processes that operate together in an integrated and mutually facilitory manner.

If the human central nervous system has any one salient characteristic, it is an extremely large capacity for storing information -- and procedures for processing information. Yet, a second all to familiar characteristic of human cognition is the limitation in processing capacity that is revealed whenever one is required to perform two or more information processing tasks simultaneously. Studies of dual-task performance have shown, however, that with practice, a controlled, resource-limited process can become in effect an automatic, data-limited process (Norman &

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Bobrow, 1975). Moreover, such an automatic process does not degrade performance on some other task with which it is performed concurrently. Given the large storage capacity available, there is clearly great potential for a learner to develop automatic skills for handling a variety of information-processing tasks, and these automated skills will enable the learner to meet the simultaneous processing demands of a complex task that draws upon those skills, such as that of reading. Skilled reading may, in effect, represent the culmination point in the development of a powerful multiprocessor that can simultaneously analyze word structure, make lexical identifications, and process discourse structures, and do all this in an integrated fashion.

The research project I shall report on here represents our attempt to identify component skills involved in reading. We have been particularly interested in measuring the efficiency or degree of automaticity with which a process is carried out, and in inferring the manner or procedures used by an individual in processing information. The domain of our inquiry includes information processing that takes place (1) in decoding the printed word, (2) in analyzing and comprehending text (or discourse), (3) and in integrating contextual and perceptual information in encoding words and phrases (see Slide 1). Within these three general domains of processing, sets of component processes are distinguished: Word analysis processes deal with the encoding of multi-letter "chunks" (such as ABLE, ORN, etc), with the translation of graphemic units to the phonological units of speech, and with the retrieval of

appropriate lexical categories. Discourse analysis processes are those employed in retrieving and integrating word meanings, in comprehending the basic propositions underlying sentences, in tying concepts in a given sentence with those in previous sentences, and in inferring additional facts or events that are not explicitly presented in a text but which are nonetheless a part of the underlying meaning to be comprehended. Integrative Processes are those that permit a reader to use information from perceptual sources in conjunction with information derived from comprehension of prior text to efficiently encode subsequent words and phrases.

I would like to describe to you now some of the results of this research, both theoretical and empirical. After that, I shall say a few words about the directions that will be taken in subsequent work.

Word Analysis Processes

Five experiments were carried out in the course of building and testing a conceptual model for processing involved in the analysis of orthographic characteristics of English words. The experiments used a variety of methods and designs: these tasks, along with the component processes they are designed to measure, are shown in the next slide (slide 2). Before we take up each of these measures, there are a couple of general properties of the measures we are building which I would like to emphasize. First, our performance measures are chronometric; they are based upon subjects' reaction times, or on inferred rates of encoding information in experiments

in which we have manipulated available processing time. Our high school subjects do not typically differ from one another in their error rates in performing these perceptual and word-analysis tasks. As we shall see, however, they do differ, and quite reliably, in their processing efficiencies -- which we regard as measures of automaticity in the component skills.

Second, the measures themselves are comparisons of subjects' levels of performance for differing levels of task difficulty. They represent the penalty in processing time that a subject must pay when the information processing demands made on a process are increased. The measures are componentially specific by virtue of the choice of stimulus manipulations, which alters the processing load with respect to some single process. Our approach to measurement is in the tradition of Donder's subtractive method for isolating components contributing to a reaction time.

Referring now to the second slide, our measures of Efficiency of Grapheme Encoding are comparisons of reaction times for matching nominally similar (e.g., Aa) and physically similar letters (e.g., AA) in the Posner task (posner & Mitchell, 1967). A second measure was obtained from a masking study (Frederiksen, 1978a) in which subjects reported any unmasked letters they could see within a visual array of letters. Each stimulus word was preceeded and followed by a pattern mask. In addition, on some trials, a portion of the stimulus letters were masked during the stimulus exposure. On these crucial trials of interest, only a single bigram within the briefly presented stimulus word was exposed without masking. And on

those trials, we measured the RT increment of each additional letter position that had to be searched in locating and reporting the unmasked bigram.

Measures of our second skill component, Efficiency in Encoding Multi-letter Perceptual Units, were obtained by comparing performance in the aforementioned masking study for low frequency bigrams (e.g., KN), with that for high frequency bigrams (e.g., TH) presented in the same position. Another measure of perceptual parsing skill was obtained in a second masking study: here we varied the inter-stimulus interval between a target array and a post-stimulus masking field. Subjects again were asked to report all of the letters they could see, and the letters they reported were scored without regard for their order of report. The measure we obtained was the difference in the rate of encoding letters when subjects were shown orthographically irregular nonsense anagrams and orthographically regular pseudowords.

Measures of skill in Phonemic Translation were obtained in a pseudoword pronunciation task (Frederiksen & Kroll, 1976; Frederiksen, 1978a). We measured the increments in vocalization onset latency that were obtained as we increased the orthographic complexity of a pseudoword. Complexity was increased by increasing the number of syllables or the number of letters, or by changing the type of vowel employed from a simple vowel to a vowel digraph. Measures of Automaticity of Articulation were based upon similar comparisons of vocalization durations obtained in the pseudoword pronunciation task.

Finally, measures of Processing Depth in Word Recognition were based upon a comparison of the extent to which orthographic variables that influence times for decoding pseudowords had a similar impact when subjects processed words of high and low linguistic frequency. Note that all of our measures were defined so that high values represent inefficiencies in processing and low values represent highly efficient, automatic processing.

The results of our study of word-analysis processes were clear cut. For each of the hypothesized components and for each of the measures we have described, there were differences in the scores obtained by skilled and poorly skilled high school age readers. These groups of readers were established by classifying subjects into skill groups on the basis of their scores on the Nelson-Denny Reading Test. The high ability readers showed significantly greater efficiency when compared to low ability readers in speed of letter encoding, in scanning speed, and in encoding bigrams of low as well as high frequency. They also showed greater facility in decoding longer pseudowords, and smaller increments in vocalization time when syllabic length was increased from 1 to 2 syllables. While there were skill differences among readers in each of the components we have investigated, the most prominent ones were in creating multi-letter perceptual units and in decoding of orthographic information.

The use of multiple tasks for each component enabled us to validate the component skills analysis we have presented for the word analysis domain, using confirmatory maximum-likelihood factor

analysis (Frederiksen, 1978b). This statistical technique was used for comparing and testing four alternative skill models that attempted to account for observed covariations in task performance on specific information processing measures derived from our five tasks. Only one of the four models tested yielded a satisfactory fit to our data. The component factors in that model are described in the next slide (slide 3). The numbers in this table are the loadings of each measure on the hypothesized component factors. As you can see, they correspond closely with our expectations. It is worthy of note that there were interactions among the component skills in our sample of high school readers, which were revealed in the pattern of factor intercorrelations. In particular, readers who were skilled at perceiving the multi-letter constituents of a word or pseudoword, were also more efficient in their methods of decoding, and they tended to utilize their efficient word analysis skills in reading even the more common English words.

Integrative Processes

Turning now to the integrative processes, work has been completed on two experiments that were designed to uncover the characteristic ways in which readers integrate information derived from context with that from the printed page, as they identify words and phrases of text. I shall briefly describe the form of each experiment, along with some of the key findings.

In the next slide (slide 4), you see two sentences, each with a final word omitted. Look first at sentence 1. This sentence

provides a context for a target word, which I'm sure you will agree, could be any one of a number of possibilities: buy, do, take, see, read, tell, etc. Look now at the second sentence. Here, there are only a few words that might fit the sentence: tell, relate, present, and the like. In our experiment (Frederiksen, 1978c), we were interested in how readers use the weak context (as in the first sentence), or the strong context (as in the second), in decoding and identifying a final target word. Subjects first read the context sentence. They then pressed a button, and were shown the target word. We measured their latency in pronouncing the target word. Some of the key findings are presented in Slide 5.

"Poor" readers appeared to employ a controlled, serial process for generating contextually relevant lexical items to test against perceptual evidence, when the final word appeared. Their performance improved with the addition of a context sentence, but only when the context was strongly constraining, and even then, only when the target word was a high probability word, such as back, which was the first one they were likely to guess. Context was of little help to this group of readers when the target item was an uncommon word, such as buns, and higher probability options existed for them, such as rolls. "Good" readers, on the other hand, appeared to use a parallel, automatic process for facilitating the identification of contextually relevant lexical items. This process operates for them even when context points to a large set or domain of items, and the degree of facilitation due to context was no different for high or low probability words within the context-relevant domain. Finally, the evidence has established

that, when context is facilitative, all readers reduce their degree of bottom-up processing of orthographic information, and rely more on visual cues for recognizing the constrained target words. Orthographic variables that influence decoding latencies for recognizing words presented alone, had a lesser effect when context was provided for the word.

In a second experiment (Frederiksen, 1979; see Slide 6), subjects were presented paragraphs of contextual information in one display, followed by a target phrase to report. The phrase was flashed briefly (200 msec.). Our interest was in the effects of context (frame 1) on the amount of material that subjects could encode from the target phrase (frame 2) during that brief interval. Experimental conditions included cases where the context paragraph was presented or omitted, and where the words in the target phrase were in normal sentence order or in a scrambled order. Key results of this experiment are summarized in the next slide (see Slide 6).

Good and poor readers appeared to be differentially sensitive to linguistic regularity in the test phrase: In the absence of context, poor readers encoded substantially the same amount of information when the words in the target phrase were in random order, as they did when the words were in correct sentence order. On the other hand, good readers encoded a greater amount of information when the test phrase was linguistically regular. When a context paragraph was added, poor readers showed little improvement in the amount of information they could encode from a randomized

test phrase. In contrast, good readers showed an ability to utilize the relatively subtle constraints provided by the context paragraph in encoding words in the nonsense (randomized) version of the test phrase. And finally, when the words of the test phrase was presented in natural, sentence order, both groups of readers showed increases in the amount of material encoded, but the good readers showed the greater degree of improvement. Our conclusions were that readers of high and low ability differ in their ability to encode multi-word segments of text (for example, adjective-noun pairs), and that the high ability readers are adept in employing context as they identify these larger-than-a-single-word units.

Discourse Analysis Processes

Some promising beginnings have been made in developing componentially specific measures of discourse processes. Following the model of our earlier studies, the research has focused on a single subskill -- that of finding referents for pronouns, and has sought to identify text characteristics that influence a subject's difficulty in resolving such problems of, specifically, pronominal reference. The next slide (slide 8) shows some of the text characteristics that have been explored. For example, in the first sentence pair (a), he could potentially refer to either engineer or fireman while it can only refer to the brake lever. Now look at the sentences in (b). Here, a sentence intervenes between the pronoun they in the final sentence and its referent, Arnold and Raymond, in the initial sentence of the set. In (c), we have a set wnere an intervening sentence uses the pronoun she in the same way as does

the final sentence, to refer to Alice. (This would not be the case if the alternative intervening sentence, beginning "The sun had..." had been used.) In (d), both the referent modern advertising and pronoun it are subjects of their respective sentences. If the paraphrase of the first sentences printed at the bottom were used instead, this would not be the case. And, finally, in (e), there is, following the initial sentence, an intervening sentence that brings to the foreground an "incorrect" potential referent (interviews), and thus places the correct referent for the target pronoun -- struggles -- in the background. Each of these text variables has been explored in this research. In the experiment, the subject reads a text, sentence by sentence. From time to time, an underscore appears beneath a word (pronoun) in a current sentence, and the subject must at that time supply (vocally) the correct referent for the pronoun. However, the primary data obtained are the reading times per syllable for each sentence in the text.

Some of our preliminary findings are presented in the next slide (see Slide 9). Readers, particularly poor readers, appear to use a strategy, simply, of selecting the grammatical subject of an initial sentence as the preferred referent for a pronoun occurring in a following sentence. Their reading times were faster when the referent for a pronoun in the target sentence was the subject of the prior sentence. This result is at variance with proposals such as that of Kintsch and van Dijk (1978), that subjects develop a propositional base for each sentence as they progress through a

text. Introducing additional sentences between the initial and final sentences (i.e., between the sentence containing the referent and that containing the pronoun) results in an increase in time for finding the correct referent, presumably due to the need for memory search and retrieval. And this increase in reading time was greatest for the poorest readers. However, where it is the case that semantically related information is contained within such intervening sentences, it appears that this information has the effect of offsetting performance decrements occasioned by memory search and retrieval. And, it also turns out that bringing an incorrect but possible referent to the foreground (a noun agreeing in number and gender with the target pronoun) actually lengthens the time for finding the correct referent for a pronoun occurring subsequently. In finding references for pronouns, poor readers appeared to be aided by the prior (and similar) use of the pronoun in question in a mediating sentence. But this particular improvement in performance only occurred when there were few words intervening between the pronoun in the mediating sentence and the pronoun in the target sentence. When they encounter pronouns, good and poor readers, both, appeared to retrieve <u>all</u> of the alternative referents that are available for a pronoun (that is, nouns that agree in gender and number), and then select the referent that fits the semantic constraints of the sentence in which it occurs. This was apparent when we compared reading times for ambiguous target sentences (that allow either referent) with those for unambiguous target sentences (in which only a single meaning is correct). Reading times were greater when the target sentence was semantically

compatible with either of two prior text referents than when only one referent was sensible -- even though both referents in principle constituted a correct response. Finally, an overall estimate of time for solving a pronominal reference problem was obtained. This measure, the increase in reading time found when a pronoun was employed in place of a repeated noun, was greater for our poor readers than for our good readers.

In summary, when we manipulate a number of text variables thought to alter difficulty of resolving problems of anaphoric reference in a text, we found a consistent pattern of differences among readers of varying abilities, suggesting that there are differences in automaticity of skills employed in dealing with this problem. Note again that there were no significant differences among our readers in their rates of errors in this admittedly difficult task.

There is one final result that may bear on yet another component skill deficiency shown by poor readers: that of syntactic parsing or the analysis of a sentence into its underlying propositions. The first sentences used in our test essays included matched pairs of sentences that differred in one respect: the addition of an extra noun phrase. Note that this usually amounted to the addition of an additional case into the sentence. Poor readers showed significantly longer reading times (per syllable of course) for the more complex sentences, while good readers did not. While converging operations are not yet available for further

confirmation, this result nevertheless suggests that we may find differences among readers in psycholinguistic skills involved in analysing the conceptual structure underlying a sentence.

Conclusions

We have covered a fair amount of ground, and have found evidence for deficiencies in poorly skilled high school age readers in a host of component processes. These have been concerned with what we have termed the word analysis, discourse analysis, and integrative processing domains. Moreover, evidence from factor analytic studies we have carried out so far suggests that, while these various component skills are not highly correlated with one another, alternate measures of a single component do show appreciable intercorrelations. The implication of this result, if should it be borne out in future research, is that the sources of reading disability are not the same in all individuals. Moreover, the deficits in component skills are reflected in their degree of efficiency or automatacity, and not in their ability to correctly carry out their processing functions to completion. We believe that poorly skilled readers may have disabilities in specific components of the reading process that can be eliminated through proper training, focused on developing automaticity of processing in the area of disability. For this reason, future research will be directed at analysing the trainability of skill components, and on developing micro-computer based instructional systems for improving performance in specific reading skills.

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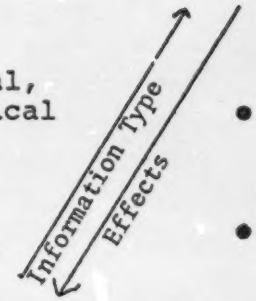
Integrative Processes

Using information derived from multiple sources (e.g., perceptual-decoding and text analysis) in an integrated decision-making system.

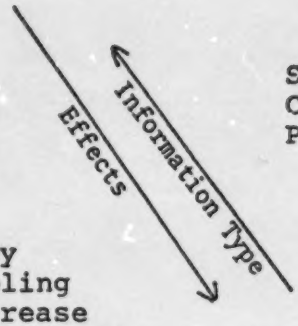
- Generating perceptual hypotheses
- Generating semantic-syntactic or text model hypotheses

Perceptual, Phonological



- Reduce level of analysis required for lexical encoding.
- Increase tendency to encode in phrasal units.

- Increase confidence in text model.
- Increase tendency to initiate sampling strategy and decrease sampling.



Semantic, Conceptual, Pragmatic

Word Analysis Processes

- Encoding multi-graphemic units.
- Translating graphemic units to phonemic units.
- Assigning appropriate speech patterns to (multi) word units (e.g., Intonation, stress, fluency).
- Retrieving lexical categories

Discourse Analysis Processes

- Retrieving word meanings.
- Constructing propositional base.
- Establishing cohesive relationships among propositions.
- Determining exophoric and endophoric (i.e., anaphora and cataphora) referents.

- -

- Constructing correspondence with pragmatic knowledge.
- Inducing and deducing information (presuppositions, possible outcomes) from the derived text base.

Figure 1. Categories of Reading Processes and the Nature of Their Interactions.

Word Analysis Processes: Component Factors

Factor	Characterization	Measures*
I.	Efficiency of Grapheme Encoding	1. Posner Letter Matching RT; RT (Aa) - RT (AA) 2. Scanning Rate in Reporting Bigrams within 4-item Arrays
II.	Efficiency in Perceptual Parsing, Encoding Orthographically Regular Multi-Letter Units	1. Increase in RT for Reporting Low Frequency compared with High Frequency Bigrams 2. Category Facilitation in the Posner Task: RT (Ad) - RT (Aa) 3. Rate of Encoding Letters in Nonsense Anagrams compared with Orthography Regular Pseudowords
III.	Efficiency in Phonemic Translation	Increase in Pseudoword Vocalization RT for: 1. Digraph Vowels compared with Simple Vowels 2. Two Syllables compared with One Syllable 3. Increases in Array Length
IV.	Automatacity in Articulation: Syllabication, Assignment of Stress and Prosodic Features	Increases in Pseudoword Vocalization Duration for: 1. Digraph Vowels compared with Simple Vowels 2. Two Syllables compared with One Syllable
V.	Depth of Processing in Word Recognition: Use of Visual/Holistic Cues versus Analysis of Orthography	Comparison of Decoding Indicators for: 1. Low Frequency and High Frequency Words 2. Pseudowords and High Frequency Words

*Measures are defined so that high values represent inefficiencies in processing and low values represent highly efficient, automatic processes.

Maximum Likelihood Estimates of Factor Loadings and Uniquenesses for the Experimental Variables*

VARIABLE	FACTOR I	II	III	IV	V	Uniqueness
1. Letter Encoding	1.00	0.	0.	0.	0.	.00
2. Scanning Speed	.64	.53	0.	0.	0.	.53
3. Percep. Facilitation	0.	.62	0.	0.	0.	.62
4. Bigram Probability	0.	.54	0.	0.	0.	.71
5. Length: Pseud.	.16	0.	.77	0.	0.	.36
6. Syll.: Pseud.	0.	0.	.80	0.	0.	.37
7. Vowel: Pseud.	0.	0.	.55	0.	0.	.70
8. Syll.: Pseud. (Dur.)	0.	0.	0.	.96	0.	.08
9. Vowel: Pseud. (Dur.)	0.	0.	0.	.36	0.	.87
10. Δ% Decod.:Pseu.-HFW	0.	0.	0.	0.	.24	.94
11 Δ% Decod.:LFW-HFW	0.	0.	0.	0.	1.00	.00

*Zero loadings were fixed by hypothesis; the goodness of fit of the hypothesized structure is measured by $\chi^2(32) = 38.4$, $p = .20$.

Slide 3

Word Recognition in Context

(1) I reminded her gently that this was
something that she really should not _____.

(2) Grandmother called the children over
to the sofa, because she had quite a story to _____.

Slide 4

Integrative Processes: Contextual Constraint of Lexical Items

	Poor Readers	Good Readers
Nature of Processing:	Controlled, Serial Generation of Contextually-Relevant Lexical Items	Automatic, Parallel Facilitation of Contextually-Relevant Lexical Items
Breadth of Application:	Operates when Context Points to a Small Number of Alternatives	Operates when Context Points to a large Domain of Items
Evidence for Controlled/ Automatic Processing:	Context Facilitates Word Recognition/ Decoding only when the Target Word has a High Probability	Context Facilitates Word Recognition/ Decoding Equally for High and Low Probability Words
Effect on Word Analysis:	Reduces Depth of Processing of Orthographic Information	Reduces Depth of Processing of Orthographic Information

Slide 5

Frame 1

They notice that the heat changes from hour to hour. So the day is carefully planned. They know it is hottest during the afternoon. So they do not work then. Instead they rest. They may take a nap. As

Frame 2

a rule they do their jobs later.

Slide 6

Integrative Processes: Contextual Constraint in Encoding Phrases

Processing Characteristics	Poor Readers	Good Readers
Encoding Linguistically Well-formed Phrases Presented in Isolation	In Absence of Context, Tendency to Encode Individual Words as though they were Independent	In Absence of Context Encode Sequentially Redundant Multi-Word Segments of Text
Contextual Facilitation of Word Recognition	Show Little Ability to Utilize Subtle Contextual Constraints that are Typical of Natural Text	Show an Ability to Utilize Subtle Contextual Constraint that are Typical of Natural Text
Contextual Facilication in Encoding Phrases	Utilize Context in Encoding Subsequent Words when They Follow in Natural Order	Utilize Context in Encoding Phrases when Subsequent Text is Presented in Natural Order

Slide 7

Discourse Processing: Finding Referents For Pronouns

(A) Number of potential referents.

The engineer told the fireman to pull the brake lever,
but HE said IT was stuck.

(B) Number of intervening sentences.

Arnold asked Raymond to play ball.
But unfortunately it started to rain.
So THEY waited for IT to stop.

(C) Mediated versus nonmediated intervening sentences.

Alice rubbed her eyes, and looked again.
She couldn't make out what had happened at all.
Was SHE in a shop?

The sun had just set, and there was little light.

(D) Parallel syntactic function.

Modern advertising does not, as a rule, seek to demonstrate
The superior quality of the product.
It plays up to the desire of Americans to conform, to
be like the Joneses.

The superior quality of the product is not, as a rule,
what modern advertising seeks to demonstrate.

(E) FOREGROUNDING THE INCORRECT REFERENT

THE CONGRESSMAN'S EARLY STRUGGLES WERE A SUBJECT HE REMINISCED ABOUT. IN TWO CANDID INTERVIEWS. THE INTERVIEWS WERE FILMED IN THE SPACIOUS CORNER OFFICE WHICH HE HAD OCCUPIED FOR THE PAST THIRTY YEARS. THEY WERE PIECES OF A PAST THAT WAS STILL CLEARLY ALIVE, AND VERY MUCH PART OF THE CURRENT PICTURE.

Slide 8 (cont'd)

Discourse Analysis Processes: Solving Problems of Pronominal Reference
(Preliminary Findings)

- Readers, particularly poor readers, use a strategy of selecting the subject of an initial sentence as the most available referent for a pronoun occurring in a following sentence.

- Sentences intervening between the initial and target sentences (i.e., between the referent and pronoun) introduce a memory search and retrieval requirement, and thus increase times for finding the correct referent for a pronoun. This increase is greater for poor readers than for good readers.

- Semantically related information within such intervening sentences can offset performance deficits occasioned by the need for memory search and retrieval.

- Bringing an incorrect, possible referent to the foreground in an intervening sentence lengthens time for finding the correct referent for a subsequently occurring pronoun.

- Poor readers appear to be aided by the prior use of a pronoun in a mediating sentence, provided that few words intervene between the two uses of the pronoun.

- Good and poor readers both appear to process all of the alternative referents available for a pronoun, when each is contextually sensible within the target sentence.

- The increase in reading time when pronominal reference is employed in place of lexical repetition is greater for poor readers than for good readers.

Slide 9